Periodic Properties Graphing Assignment

Part 1: Atomic Radius vs. Atomic Number

Introduction

In building a model of the atom it is reasonable to expect that as the number of particles in the atom increases, so should the size of the atom. However, we must remember that all electrons are located around the nucleus and that electrons *repel* each other. What do experimental results tell us about the actual size of atoms?

Many methods have used to compute and measure the size of atoms. Results vary with the methods used. The atomic radius can be determined by spectroscopic methods, by x-ray diffraction, by measurements of the properties of gases, and in other ways. These techniques are too complicated to discuss here, but we can use the results gained from such experiments.

In this activity, you will graph the radii of atoms as a function of their atomic numbers. From this graph, you can make generalizations about the relationship of atomic numbers and atomic size.

Purpose

To study the relationship between atomic number and atomic size to see whether there is a definite pattern.

Table of Atomic Radii in Angstroms (1 A = $1x10^{-10}$ m)

1	H	0.37	15	P	1.10	29	Cu	1.28	42	Mo	1.36
2	He	0.31	16	S	1.04	30	Zn	1.33	43	Tc	1.30
3	Li	1.52	17	Cl	0.99	31	Ga	1.22	44	Ru	1.33
4	Be	1.11	18	Ar	0.95	32	Ge	1.22	45	Rh	1.34
5	B	0.88	19	K	2.31	33	As	1.21	46	Pd	1.38
6	C	0.77	20	Ca	1.97	34	Se	1.17	47	Ag	1.44
7	N	0.70	21	Sc	1.60	35	Br	1.14	48	Cd	1.49
8	O	0.66	22	Ti	1.46	36	Kr	1.10	49	In	1.62
9	F	0.64	23	V	1.31	37	Rb	2.44	50	Sn	1.40
10	Ne	0.60	24	Cr	1.25	38	Sr	2.15	51	Sb	1.41
11	Na	1.86	25	Mn	1.29	39	Y	1.80	52	Te	1.37
12	Mg	1.60	26	Fe	1.26	40	Zr	1.57	53	I	1.33
13	Al	1.43	27	Co	1.25	41	Nb	1.43	54	Xe	1.30
14	Si	1.17	28	Ni	1.24						

Procedure

1. Using a computer (or by hand), construct a full-page graph with atomic numbers on the *x*-axis and atomic radii on the *y*-axis. Make sure you choose an appropriate scale, and include labeled axes and a graph title.

2. Make sure your graph shows each data point. Join the points with a black line.

3. Find the points that indicate the elements that have the maximum number of electron in their outermost energy level. Divide the graph into sections by drawing a vertical red line through these points.

Tabulation of Results

1. List in separate vertical columns:
   a. the symbols and atomic numbers of the elements through which the red lines pass.
   b. the symbols and atomic numbers of the elements with the smallest atomic radius in each section of the graph.
   c. the symbols and atomic numbers of the elements with the largest atomic radius in each section of the graph.
2. List in a horizontal row:
   a. the symbol and atomic number of the elements in which 3*d* orbitals are filling.
   b. the symbol and atomic number of the elements in which 4*d* orbitals are filling.

Questions

1. Note the regular, *repeating* pattern in each section of the graph (what is between the red lines).
   a. How do these sections refer to the periodic table?
   b. How can you explain this pattern?
   c. When a new section starts, what happens to atomic radius? Explain why.
2. What can you say about the trend in atomic radius as the atomic number increases within a group on the periodic table? Give a reason for this trend.
3. Look at the elements on your graph that have electrons filling the *d* orbitals. What trend do you see regarding their atomic radius as their atomic number increase? Give a reason for this trend.

Part 2: Ionization Energy vs. Atomic Number

Introduction

The last section considered neutral atoms in their ground state. Chemists have found that, by supplying sufficient energy, they can remove the most loosely held electron in the atom. The atom is thereby made into a positive ion. Such ion is called a cation. The energy required for this process is referred to as the *ionization energy*. This energy can be measured in electron-volts (eV). You do not need to be concerned at this time with the definition of an electron-volt, other than to know that it is a quantity of energy.

You have discovered that the atomic number of an element is an important factor in relation to electron configuration and atomic radius. Are atomic number and ionization energy also related? In this activity, you will plot ionization energy versus atomic number in an attempt to answer this question.

Purpose

To study the relationship between atomic number and ionization energy to see whether there is a definite pattern.

Table of Ionization Energies in Electron-Volts (1 eV = 1.602×10^{-19} J)

1	H	13.5	15	P	11.0	29	Cu	7.7	42	Mo	7.2
2	He	24.5	16	S	10.4	30	Zn	9.4	43	Tc	7.3
3	Li	5.4	17	Cl	13.0	31	Ga	6.0	44	Ru	7.5
4	Be	9.3	18	Ar	15.8	32	Ge	8.1	45	Rh	7.7
5	B	8.3	19	K	4.4	33	As	10.5	46	Pd	8.3
6	C	11.2	20	Ca	6.1	34	Se	9.7	47	Ag	7.6
7	N	14.5	21	Sc	6.6	35	Br	11.8	48	Cd	9.0
8	O	13.6	22	Ti	6.8	36	Kr	14.0	49	In	5.8
9	F	17.3	23	V	6.7	37	Rb	4.2	50	Sn	7.3
10	Ne	21.5	24	Cr	6.8	38	Sr	5.7	51	Sb	8.6
11	Na	5.1	25	Mn	7.4	39	Y	6.6	52	Te	9.0
12	Mg	7.6	26	Fe	7.9	40	Zr	7.0	53	I	10.4
13	Al	6.0	27	Co	7.9	41	Nb	6.8	54	Xe	12.1
14	Si	8.1	28	Ni	7.6						

Procedure

1. Using a computer (or by hand), construct a graph with atomic numbers on the *x*-axis and ionization energy on the *y*-axis. Make sure you choose an appropriate scale, and include labeled axes and a graph title.

2. Make sure your graph shows each data point. Join the points with a black line.

3. Find the points that indicate the elements that have the highest ionization energies. Divide the graph into sections by drawing a vertical red line through these points. These are represented by the peaks on your graph.

Tabulation of Results

1. List in separate vertical columns the elements having:

    a. the highest ionization energy in each section of the graph

    b. the lowest ionization energy in each section of the graph

    c. the next-to-highest ionization energy in each section of the graph (do not list the elements on the red lines

Questions

1. Look at the graph for ionization energy vs atomic number:
    a. Describe the overall pattern formed by your graph within each section.
    b. What happens when a new section of the graph starts? Explain why.
    c. Explain what happens to ionization energy in the transitions between:
        s and *p* orbitals
        d and *p* orbitals
2. Explain the affect atomic number has on ionization energies within **groups and periods** on the periodic table. Give reasons for your answers.
3. Place the graph of ionization energies on top of the graph of atomic radii and view them together against a strong light. What can you conclude about the trend shown by these two properties as plotted against atomic number?
4. Generally, why are the same elements grouped together again and again both when properties are plotted against atomic number and on the periodic table?
5. Using the information gleaned from these two exercises and from class, make a **general statement** about the *properties* of elements in relation to their atomic numbers.